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Agent certificateur/Certifying Officer

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MULTIPLEX HIERARCHY FOR HIGH CAPACITY TRANSPORT SYSTEMS

Field of the Invention

This invention is concerned with a method of extending the ITU-T G.707 multiplex hierarchy for very high capacity transport systems, through the creation of a new virtual container and its associated pointer.

SUMMARY OF THE INVENTION

Inherent with this method is the development of a new virtual container, VC-5 and its associated pointer, AU-5. The method of the invention has as an object to reduce the number of pointers on the high capacity line. The present invention provides for a hierarchy based on extrapolation of the SONET SPE and multiplex structure up to high capacity. This would create an STS pointer density of, for example, 768 pointers on a 40Gbps channel.

This method also introduces the concept of nesting pointers, so that a very high rate network (VHRN) does not see the STS-1 / STM-1 pointer granularity. It is generally acknowledged there are significant benefits associated in nesting pointers with respect to reduced complexity and pointer processing.

A path overhead is necessarily added for monitoring purposes within the network. For OAM of the constituent VHRN payloads it may be advantageous to provide a VHRN path overhead for certain tributary levels, i.e. for fault and performance management. This path overhead has a minimum granularity of an STS-12 / STM-4 SPE. It is to be understood that this granularity is by way of example only, and that the present invention is not limited to this rate.

Synchronous multiplexing is also considered by the method according to this invention.

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BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of the preferred embodiments, as illustrated in the appended drawings, where:

Figure 1 shows the multiplexing hierarchy as detailed in G.707;

Figure 2 shows the relationship between various multiplexing elements;

Figure 3 shows the multiplexing method directly from AU-3 using TU-3;

Figure 4 is the translation of AU-3 to TU-3;

Figure 5 is the translation of AU-3-3c/AU-4 to TU-4;

Figure 6 is the translation of AU-3-12c/ AU-4-4c/AU-3-12 /AU4-4 to TU-5;

Figure 7 is the translation of AU-3-48c/AU-4-16c to TU-5-4c

Figure 8 is the translation of AU-3-192c/AU4-64c to TU-5-16c;

Figure 9 is the translation of AU-3-768c/AU4-256c to TU-5-64c;

Figure 10 shows the mapping of a TUG-3 into a VC-4

Figure 11 shows the mapping of a VC-4 into a TU-4;

Figure 12 shows the mapping of a TUG-4 into a TUG-5;

Figure 13 shows the mapping of a TUG-5 into a VC-5;

Figure 14 illustrates the mapping of a TUG-5-nc into a VC-5-nc;

Figure 15 shows thVC-5-nc concatenation;

Figure 16 illustrates the mapping of a C-5 into a VC-5;

Figure 17 illustrates the mapping of a C-5-nc into a VC-5-nc

Figure 18 illustrates the frame structure for the 40GBps VHRN;

Figure 19 is a block diagram of how the multiplex hierarchy may be extended for a VC-6 granularity;

Figure 20 is a block diagram of how the multiplex hierarchy may be extended for non-SDH/SONET formats and

Figure 21 show the frame structure for Byte interleaved at AU-3 or AU-4.

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DESCRIPTION OF THE PREFERRED EMBODIMENT

The following assumptions are used in the ensuing implementation, by way of example:

- The TDM line rate of the VHRN is assumed to be ~40GBps.
- The frame size of the 40GBps is equivalent to the frame size for byte interleaving 256 STM-1s / 768 STS-1s.

The multiplex hierarchy will be considered from a functional perspective. Consideration with respect to existing hardware is beyond the scope of this invention.

Figure 1 shows the multiplex hierarchy as detailed in G.707. G.707 multiplex hierarchy relies on multiplexing units at a granularity of AU-3s or AU-4s. For an AU-3 multiplex hierarchy (analogous to the GR.253, STS-1 multiplex hierarchy) extended to a 40GBps line this results in 768 AU-3 pointers on the multiplex line. For AU-4 multiplexing (STM-1) this results in 256 AU-4 pointers on the multiplex line. For very high capacity transport systems, granularity of this order is not required and indeed adds significant complexity to the VHRN product.

This invention is concerned with a method of extending the ITU-T G.707 multiplex hierarchy for very high capacity transport systems, through the creation of a new virtual container VC-5 and its associated pointer, AU-5. The new virtual container has an effective payload area equivalent to a STM-4/STS12 SPE. In addition, the novel hierarchy provides translation of AU-3-ns and AU-4-ns into tributary units (TUs).

It is however to be understood that the invention is applicable for other rates. The conventions and terminology used in this document are in line with G.707.

Definitions

Synchronous Transport Module (STM):

A STM is the information structure used to support section layer connections in the SDH. It consists of information payload and section overhead (SOH) information fields organized in a block frame structure which repeats every 125 microseconds. The information is suitably conditioned for serial transmission on the selected media at a rate, which

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is synchronized to the network. A basic STM is defined at 155 520 kbit/s. This is termed STM-1 and is analogous to the GR.253 SONET STS-3. Higher capacity STMs are formed at rates equivalent to N times multiples of this basic rate.

A STM-N as detailed in G.707 can contain byte interleaved AU-3s or AU-4s. For AU-3 byte interleaving the STM-N will contain Nx3 AU-3s; for AU-4 byte interleaving the STM-N will contain N AU-4s.

The STM-N described in this document contains $N/4$ AU-5s which are byte interleaved together.

Virtual Container-n (VC-n):

A virtual container is the information structure used to support path layer connections in the SDH. It consists of information payload and path overhead (POH) information fields organized in a block frame structure which repeats every 125 microseconds. Alignment information to identify VC-n frame start is provided by the server network layer.

Two types of virtual containers have been identified; higher order and lower order virtual containers:

– Lower order virtual container-n: VC-n ($n = 1, 2$)

This element comprises a single container-n ($n = 1, 2$) plus the lower order virtual container POH appropriate to that level.

- Higher order virtual Container-n: VC-n ($n = 3, 4, 5$)

G.707 describes virtual containers up to a VC-4. This document describes a new higher order virtual container, VC-5. The higher order containers comprise either a single container-n ($n = 3, 4, 5$) or an assembly of tributary unit groups (TUG-2s, TUG-3s, TUG-4s or TUG-5), together with virtual container POH appropriate to that level.

VCs are equivalent to the SONET VT and STS SPEs. The lower order virtual containers comprise VT1.5 SPE, VT2 SPE and VT6 SPE. The higher order virtual containers comprise STS-1 SPE and STS-3c SPE.

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Administrative Unit-*n* (AU-*n*):

An administrative unit is the information structure, which provides adaptation between the higher order path layer and the multiplex section layer. It consists of an information payload (the higher order virtual container) and an administrative unit pointer, which indicates the offset of the payload frame start relative to the multiplex section frame start.

Three administrative units are defined. The AU-5, which is described in this document, consists of a VC-5 plus an administrative unit pointer which indicates the phase alignment of the VC-5 with respect to the STM-N frame. The AU-4 and AU-3, which are detailed in G.707, consist of a VC-4 or VC-3, respectively, plus an administrative unit pointer, which indicates the phase alignment of the VC with respect to the STM-N frame.

In each case the administrative unit pointer location is fixed with respect to the STM-N frame. One or more administrative units occupying fixed, defined positions in an STM payload is termed an administrative unit group (AUG).

An AUG 1 consists of a homogeneous assembly of AU-3s or an AU-4.

An AUG-4 consists of a homogeneous assembly of AU-3s or AU-4s or an AU-5.

AU-*n* is equivalent to the SONET STS. An AU-3 is equivalent to an STS-1; an AU-4 is equivalent to an STS-3c.

Tributary Unit-*n* (AU-*n*):

A tributary unit is an information structure, which provides adaptation between the lower and higher order path layer. It consists of an information payload (the lower or higher order virtual container) and a tributary unit pointer, which indicates the offset of the payload frame start relative to the higher order virtual container frame start.

G.707 described tributary units up to TU-3. The present invention extends the concept of the TU-*n* for *n* = 1, 2, 3, 4, 5. The TU-*n* consists of a VC-*n* together with a tributary unit pointer. One or more tributary

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units, occupying fixed, defined positions in a higher order VC-n payload is termed a tributary unit group (TUG). TUGs are defined in such a way that mixed capacity payloads made up of different size tributary units can be constructed to increase flexibility of the transport network.

A TUG-2 consists of a homogeneous assembly of identical TU-1s or a TU-2.

A TUG-3 consists of a homogeneous assembly of TUG-2s or a TU-3.

A TUG-4 consists of a homogeneous assembly of TUG-3s or a TU-4.

A TUG-5 consists of a homogeneous assembly of TUG-4s or a TU-5.

Container-n (C-n):

A container is the information structure, which forms the network synchronous information payload for a virtual container. For each of the defined virtual containers there is a corresponding container. Adaptation functions have been defined for many common network rates into a limited number of standard containers.

The capacity of each container is detailed in Table 1.

Table 1: Payloads for C-n

VHRN		G.707 Container-n	
Container – n (C-n)	Payload (MBps)	(C-n)	Payload (MBps)
C-3[1]	48.384	C-3	48.384
C-4[1]	149.760	C-4	149.760
C-5	603.648[2]	C-4-4c	599.040
C-5-4c	2,414.592[2]	C-4-16c	2,396.160
C-5-16c	9,658.368[2]	C-4-64c	9,584.640
C-5-64c	38,633.472[2]	C-4-256c	38,338.560

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Notes:

1. C-3 and C-4 are defined in G.707. Only C-5 and concatenations thereof are new containers for the VHRN multiplex hierarchy.

2. For the VHRN hierarchy the payload for a C-n, where n >= 5, is slightly larger than the corresponding G.707 container. This is due to the extra columns allocated for nesting pointers in an AU-n to TU-n translation. For example for a C-5 these columns are unused and may therefore be allocated for payload.

3. C-6, C-7 and C-8 map into a VC5-n. At this stage path overhead is added. To maintain the AU-5 frame size columns of fixed stuff are added. For a C-5-4c there will be one column of path overhead and three columns of fixed stuff. Although it may seem advantageous to remove these additional columns of fixed stuff for the C-5-4c mapping and assign them as payload; in the interests of scalability this should not be performed. As the hierarchy scales and a VC-6 and AU-6 are created the TUG-6 (TUG-5-4c, in this hierarchy) will map into a VC-6 instead of a VC-5-4c. This mapping will add a column of path overhead but no fixed stuff. If for the AU-5 hierarchy the C-5-4c container had been increased to use the columns of fixed stuff it would now be too large to map into a VC-6.

A pointer is an indicator whose value defines the frame offset of a virtual container with respect to the frame reference of the transport entity on which it is supported.

Concatenation is a procedure by which tributaries are adapted into Virtual Containers at the boundary of the synchronous network.

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SDH <u>Multiplexing</u> is a procedure by which lower multiple lower order path layer signals are adapted into a higher order path or the multiple higher order path layer signals are adapted into a multiplex section.

SDH <u>aligning</u> is a procedure by which the frame offset information is incorporated into the Tributary Unit or Administrative Unit when adapting to the frame reference of the supporting layer.

TU <u>pointer transformation</u> is a procedure whereby the Administrative Unit pointer is adapted to become a Tributary Unit pointer, i.e. the AU pointer is removed from the overhead and placed in the payload.

VHRN Multiplexing Structure

Figure 2 shows the relationship between various multiplexing elements. TUGs are defined in such a way that mixed capacity payloads made up of different size tributary units can be constructed to increase flexibility of the transport network.

This multiplexing hierarchy provides a single pointer at the STM-4/STS-12 level and path overheads at SPEs>= STM-4/STS-12.

Figure 3 shows how an AU-3 is multiplexed using this hierarchy.

Translation of AU-n to TU-n

The possible SDH/SONET tributary interfaces to the VHRN are defined in Table 2. Upon receipt of these signals at the VHRN the section overhead will be terminated. This leaves either an AU-3-n or an AU-4-n or concatenations thereof. The relationship between the tributaries and their corresponding AU-n is shown in Table 2.

The primary requirement of the high capacity multiplex hierarchy is to reduce the number of pointers on the high capacity line. For AU-3 and AU-4 byte interleaved systems the pointers are presented to the line at a granularity of STS-1 or STM-1, respectively. For a 40GBps (STM-256/STS-768) this will result in potentially 768 pointers on the line.

In order for synchronous traffic which has been created using byte interleaved AU-3s and AU-4s to be carried on the VHRN the pointers of

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the traffic signals must be hidden from the line, i.e. through nesting pointers. G.707 has already standardized a method for nesting pointers for lower order containers, see Figure 1. This is achieved through the use of TUs (Tributary Units).

In order to "hide" the tributary pointers from the high capacity line the tributary AU ns are translated to TU-ns. The translation from AU-n to corresponding TU-n is detailed in Table 2. The information content and pointers of both structures are identical; it is only the position of the pointers with respect to the payload which has changed. The TU-ns will then be packaged into TUG-5s and an AU-5 pointer assigned.

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Table 2 Relationship between Synchronous Module, AU-n and TU-n

Tributary Interface to the VHRN		Section OH Termination of tributaries	Translation for processing in VHRN Multiplex Hierarchy
SDH	SONET	AU-n	TU-n
STM-0	STS-1	AU-3	TU-3^2
	STS-3c	AU-3-3c	TU-4
	STS-12c	AU-3-12c	TU-5
	STS-48c	AU-3-48c	TU-5-4c
	STS-192c	AU-3-192c	TU-5-16c
	STS-768c	AU-3-768c	TU-5-64c
STM-1		AU-4	TU-4
STM-4-4c		AU-4-4c	TU-5
STM16-16c		AU-4-16c	TU-5-4c
STM-64-64c		AU-4-64c	TU-5-16c
STM-256-256c		AU-4-256c	TU-5-64c
	STS-3	AU-3-3	TU-4
	STS-12	AU-3-12	TU-5
	STS-48	AU-3-48	TU-5-4
	STS-192	AU-3-192	TU-5-16
	STS-768	AU-3-768	TU-5-64
STM-4		AU-4-4	TU-5
STM-16		AU-4-16	TU-5-4
STM-64		AU-4-64	TU-5-16
STM-256		AU-4-256	TU-5-64

We note that the tributary interfaces described are SDH/SONET in nature. Other interfaces (1G Ethernet) may also be supported, an investigation of optimization of the hierarchy for other tributary interfaces is for further study. (i.e. 1G Ethernet may be mapped into a TU-5-2c).

The TU-3 is defined in G.707, all other tributary units which are described, i.e. TU-4 and TU-5, are an extension to the G.707 hierarchy.

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Translation of AU-3 to TU-3

The TU-3, as defined in G.707, consists of a VC-3 with a 9-byte VC-3 POH and the TU-3 pointer. The first column of the 9-row by 86-column TU-3 is allocated to the TU-3 pointer (bytes H1, H2, H3) and fixed stuff. The phase of the VC-3 with respect to the TU-3 in indicated by the TU-3 pointer. The translation from AU-3 to TU-3 relies on removing the columns of fixed stuff within the AU-3 payload.

Translation of AU-3-3c / AU-4 to TU-4

Figure 5 shows a translation from an AU-4 to an TU-4. The AU-4 could contain a VC-4 or a STS3c. The TU-4 consists of a VC-4 with a 9-byte VC-4 POH and the TU-4 pointer. The first column of the 9-row by 262-column TU-4 is allocated to the TU-4 pointer. The phase of the VC-4 with respect to the TU-4 in indicated by the TU-4 pointer.

Translation of AU-3-12c / AU-4-4c to TU-5

Figure 6 shows a mapping from an AU-3-12 (AU-3-12-c) or an AU-4-4 (AU-4-4c) signal into a TU-5. Non-concatenated STM-N signals where n>4 shall also be processed as AU-5s. G.707 requires such signal to be demultiplexed to the STM-1 level and byte interleaved as AU-4s. Using the AU-5 method it is now only necessary to demultiplex the signals to AU-5 granularity. The first 4-columns of the 9-row by 1048-column TU-5 is allocated to the TU-5 pointer. The phase of the VC-5 with respect to the TU-5 in indicated by the TU-5 pointer.

Translation of AU-3-48c / AU-4-16c to TU-5-4c

Figure 7 shows a mapping from an AU-3-48c or an AU-4-16c signal into a TU-5-4c. The first 4x4-columns of the 9-row by 1048x4-column TU-5-4c is allocated to the TU-5-4c pointer. The phase of the VC-5-4c with respect to the TU-5-4c in indicated by the TU-5-4c pointer.

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Translation of AU-3-192c / AU-4-64c to TU-5-16c

Figure 8 shows a mapping from an AU-3-192c or an AU-4-64c signal into a TU-5-16c. The first 4x16-columns of the 9-row by 1048x16-column TU-5-16c is allocated to the TU-5-16c pointer. The phase of the VC-5-16c with respect to the TU-5-16c in indicated by the TU-5-16c pointer.

Translation of AU-3-768c / AU-4-256c to TU-5-64c

Figure 9 shows a mapping from an AU-3-768c or an AU-4-256c signal into a TU-5-64c. The first 4x64-columns of the 9-row by 1048x64-column TU-5-64c is allocated to the TU-5-64c pointer. The phase of the VC-5-64c with respect to the TU-5-64c in indicated by the TU-5-64c pointer.

Figures 10 to 15 show mappings and multiplexing the tributary groups which have been defined in the hierarchy.

Mapping TUG-3s into a VC-4

The arrangement of three TUG-3s multiplexed into a VC-4 is shown in Figure 10. The TUG-3 is a 9-row by 86-column structure. The VC-4 consists of one column of VC-4 POH, two columns of fixed stuff and a 258 column payload structure. The three TUG-3s are single byte interleaved into the 9-row by 258-column VC-4 payload structure and have a fixed phase with respect to the VC-4.

Mapping a VC-4 into a TU-4

The mapping of a VC-4 into a TU-4 is shown in Figure 11. The TU-4 consists of the VC-4 and the TU-4 pointer. The phase of the VC-4 with respect to the TU-4 is indicated by the TU-4 pointer (H1, H1, H1, H2, H2, H2, H3, H3, H3).

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Multiplexing a TUG-4 into a TUG-5

The multiplexing structure for the TUG-4 via the TUG-5 is depicted in Figure 12. The TUG-5 is a 9-row by 1048-column structure, which is created by single byte interleaving the TUG-4s.

Mapping a TUG-5 into a VC-5

The mapping of a TUG-5 into a VC-5 is shown in Figure 13. The TUG-5 is a 9-row by 1048-column structure. The VC-5 consists of one column of VC-5 POH and a 1048 column payload structure. Note that the VC-5 path overhead has not yet been defined, this is for further study.

Mapping a TUG-5-nc into a VC-5-nc

G.707 defines concatenated payloads at the VC-4 level. As a larger AU pointer and virtual container have been defined it is now possible to perform concatenation at the VC-5 level. Figure 14 shows the mapping from a TUG-5-nc into a VC-5-nc, where N defines the level of concatenation, $N = 4, 16, 64$. Figure 15 shows the frame size for a concatenated VC-5.

Concatenated tributary units are a new concept from G.707. To indicate the concatenated nature of the payload there must be a concatenation indicator assigned in the VC-5 path overhead. This is required to prevent misconnection of the concatenated VC-5 payload.

Mapping a C-5 into a VC-5

The mapping of a C-5 into a VC-5 is shown in Figure 16. The C-5 is a 9-row by 1048-column structure. The VC-5 consists of one column of VC-5 POH and a 1048 column payload structure.

Mapping a C-5-nc into a VC-5-nc

The mapping of a C-5-nc into a VC-5-nc is shown in Figure 17. The C-5-nc is a 9-row by 1048xN-column structure. The VC-5 consists of one column of VC-5 POH, N-1 columns of fixed stuff and a 1048xN column payload structure.

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AU-5 Pointer Definition

The AU-5 pointer can be optimised for system performance. H3 may vary from one to twelve bytes. One H1 byte and one H2 byte are required.

AU-5 Path Overhead

The path overhead will be align with the VC-4 path overhead detailed in G.707. In addition, a concatenation indicator is required in the overhead.

TUG-n Numbering Scheme

A numbering scheme is required to locate the TUG-ns within the VHRN. G.707 defines a three figure address (K, L, M) where K represents the TUG-3 number, L the TUG-2 number and M the TU-1 number. This can logically be extended to include TUG-4 and TUG-5.

Table 1 TUG-n Numbering Scheme

TUG-n	Address	Range of values
TUG-5	I	1,2,3,4
TUG-4	J	1,2,3,4
TUG-3	K	1,2,3

AU-5 Numbering Scheme

A numbering scheme is required to locate the AU-5s within the VHRN line. G.707 defines a two figure address (A, B) where A represents the AU-3 number and B the AU-4 number. This can logically be extended to include the AU-5.

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Table 2 AU-*n* Numbering Scheme

AU-*n*	Address	Range of values
AU-5	C	1,2,3,4
AU-4	B	1,2,3,4
AU-3	A	1,2,3

Frame Structure of the VHRN

The STM-256/STS-768 frame structure for a VHRN is shown
Figure 18. The three main areas of the frame are indicated:

- SOH
- Administrative unit (AU-5) pointers
- Information payload

Figure 21 details the frame structure for a STM-256 signal which
has been created by byte interleaving AU-3s or AU-4s In order to retain
the 40GBps bit rate the frame size for the VHRN must be kept the same
as the AU-3/AU-4 byte interleaving. Figure 20 shows the frame size and
OH allocation for a 40GBps line signal which has been created by byte
interleaving 768 AU-3s or 256 AU-4s.

As the payload is larger due to the nested pointers of the
constituent payloads it is therefore necessary to reduce the byte
allocation for the section and line overheadaintain a line rate in even
multiples of the existing SONET/SDH line rates.

This approach has assumed scaling the G.707 frame. It may be
optimal to define embed the FEC and OH within the frame..

Scalability to VC-6 and AU-6

The multiplex hierarchy in this invention is designed to be scalable
to higher order virtual containers, i.e. VC-6. Figure 19 shows how this
multiplex hierarchy may be extended for a VC-6 and its associated AU-6.

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The same principles as defined here can be applied to scale the granularity of the hierarchy as the network demands increase.

Optimization for non-SONET/SDH Tributaries

It is possible to optimize this hierarchy for transport of non-SDH/SONET formats. An example of how this can be implemented is shown in Figure 20, where a 1Gbps ethernet signal is mapped into a C-5-2c which represents a STM-8. This principle can be extended to other non-SONET/SDH rates as currently defined.
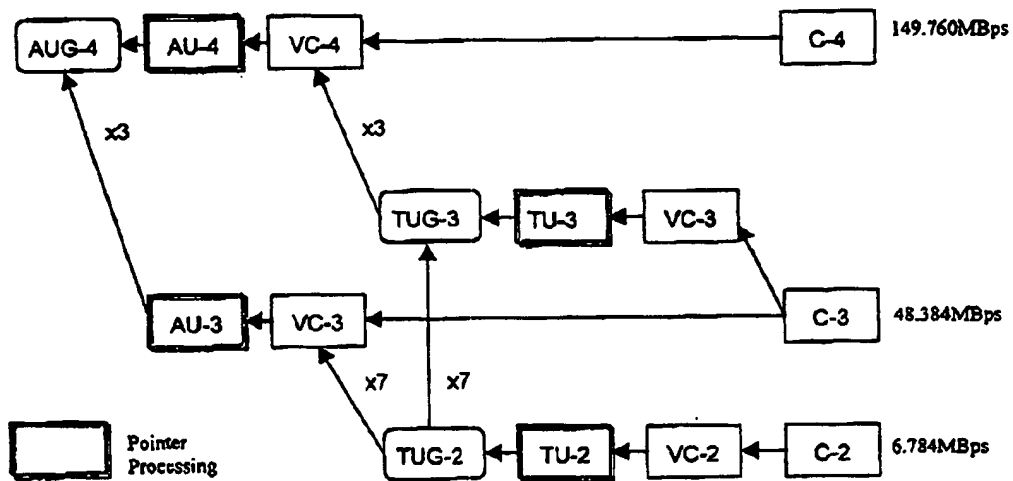
FIGURE 1
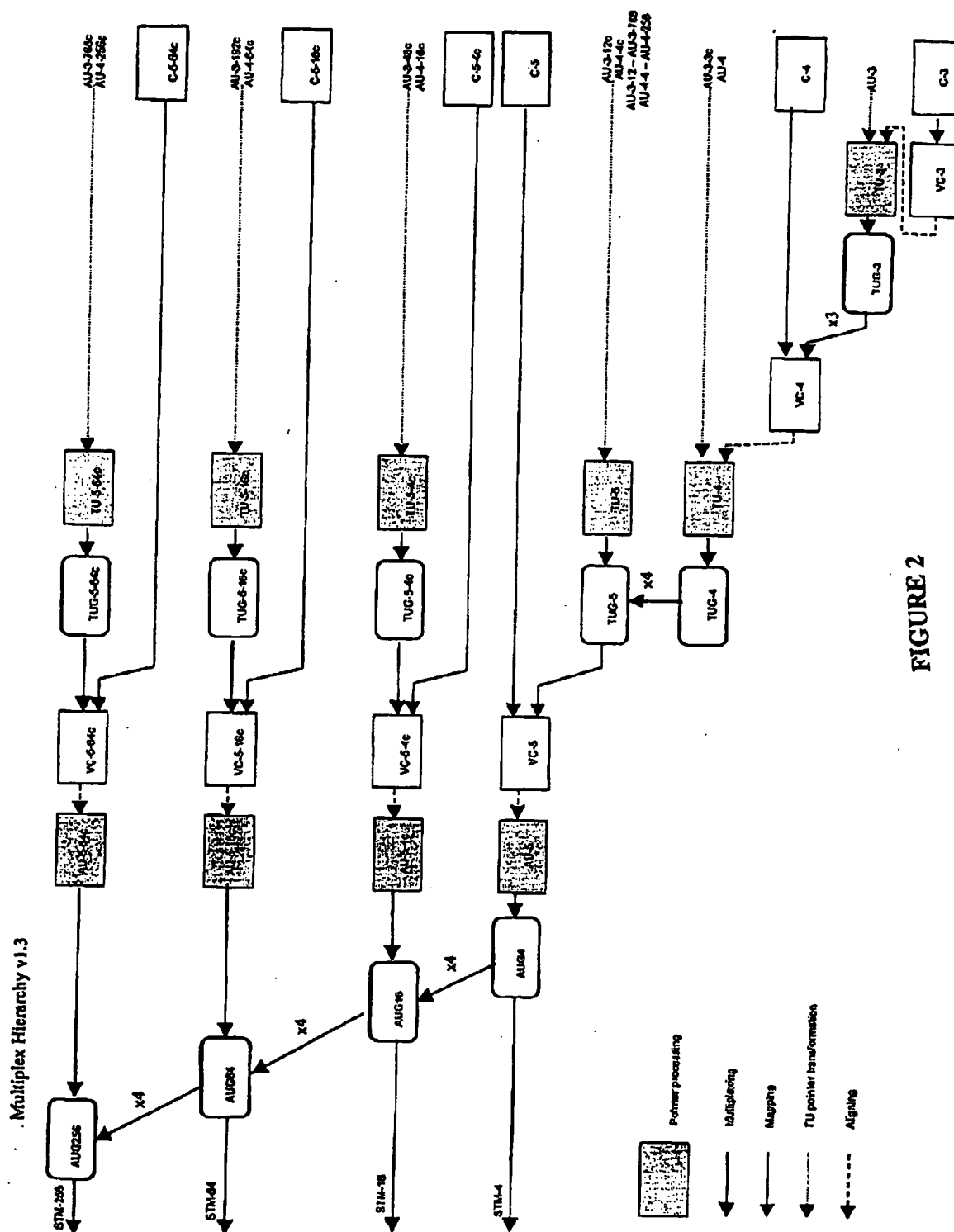
FIGURE 2

Multiplex Hierarchy v1.3
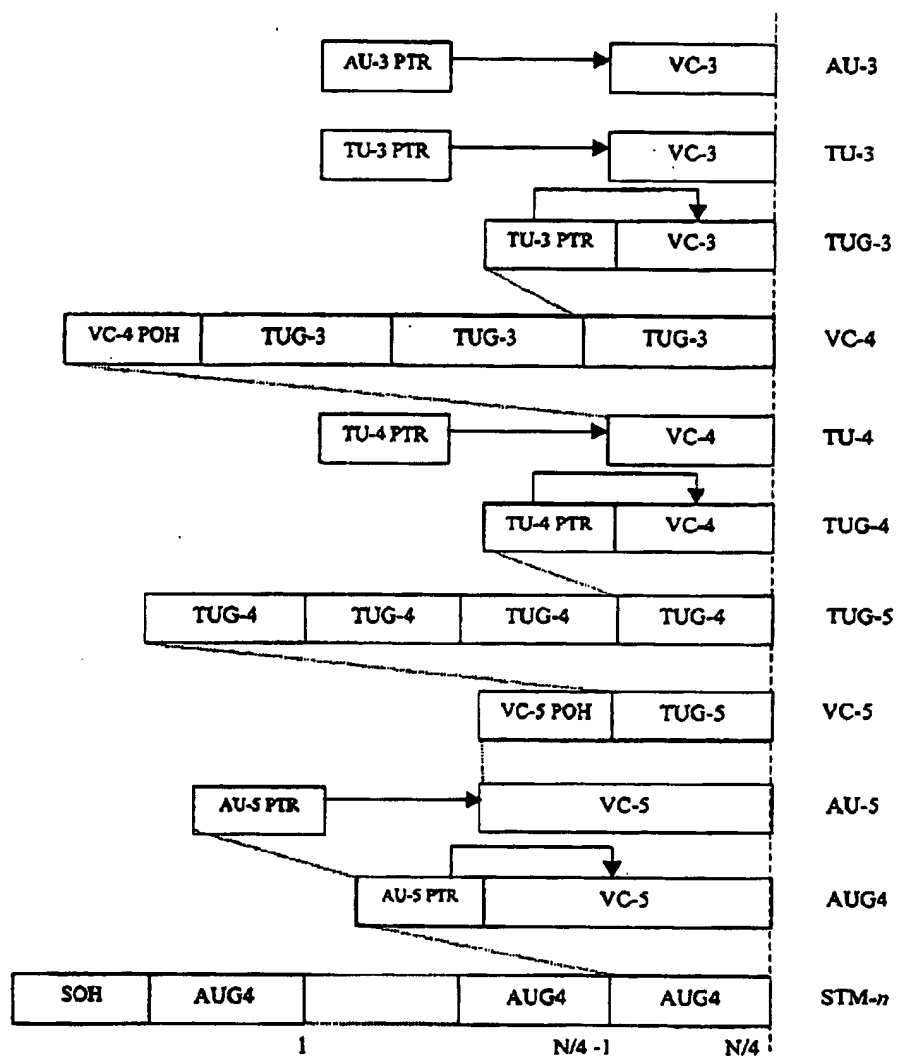
FIGURE 3
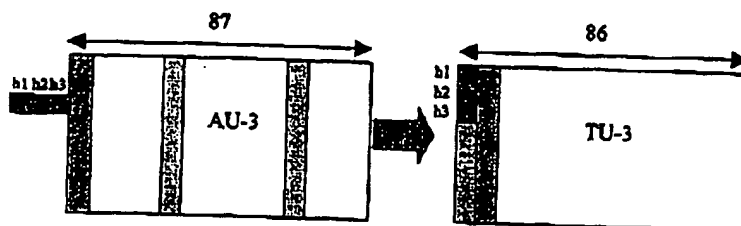
FIGURE 4
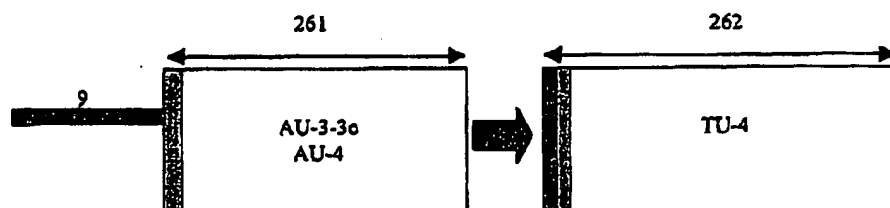
FIGURE 5
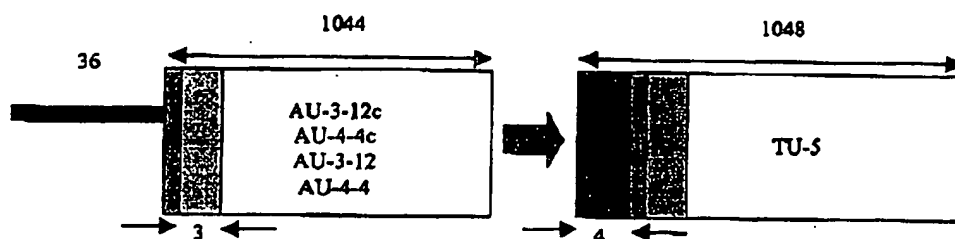
FIGURE 6
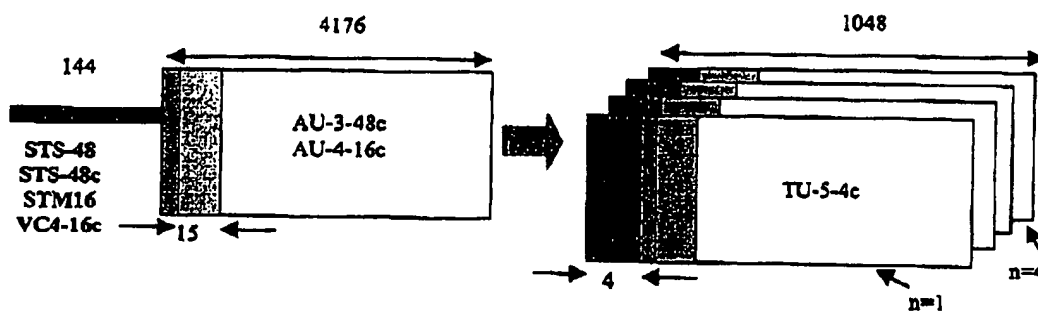
FIGURE 7
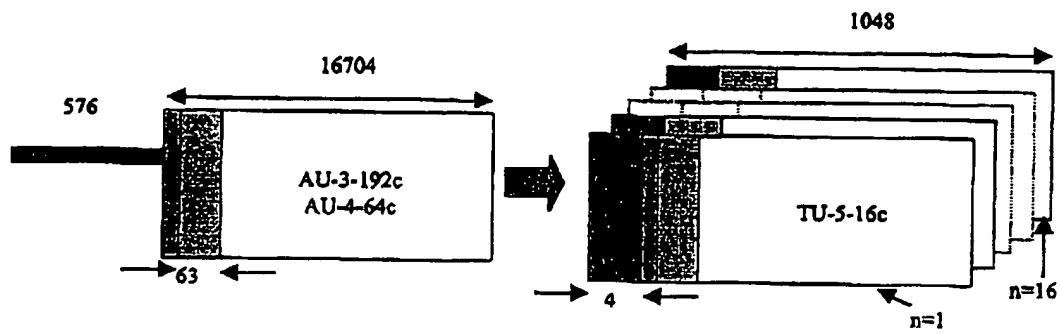
FIGURE 8
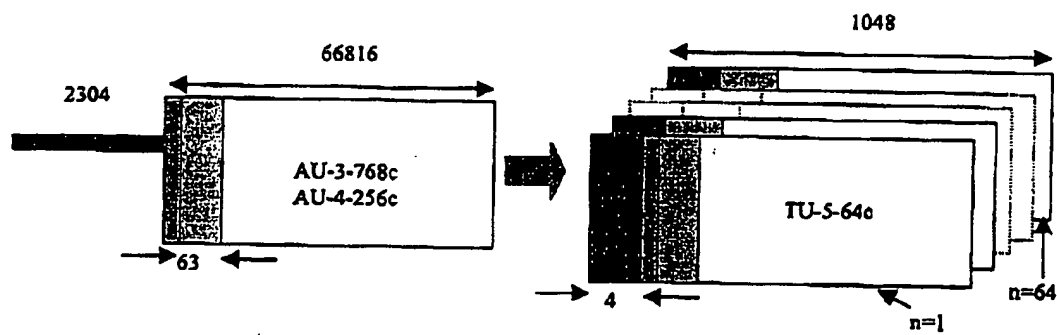
FIGURE 9
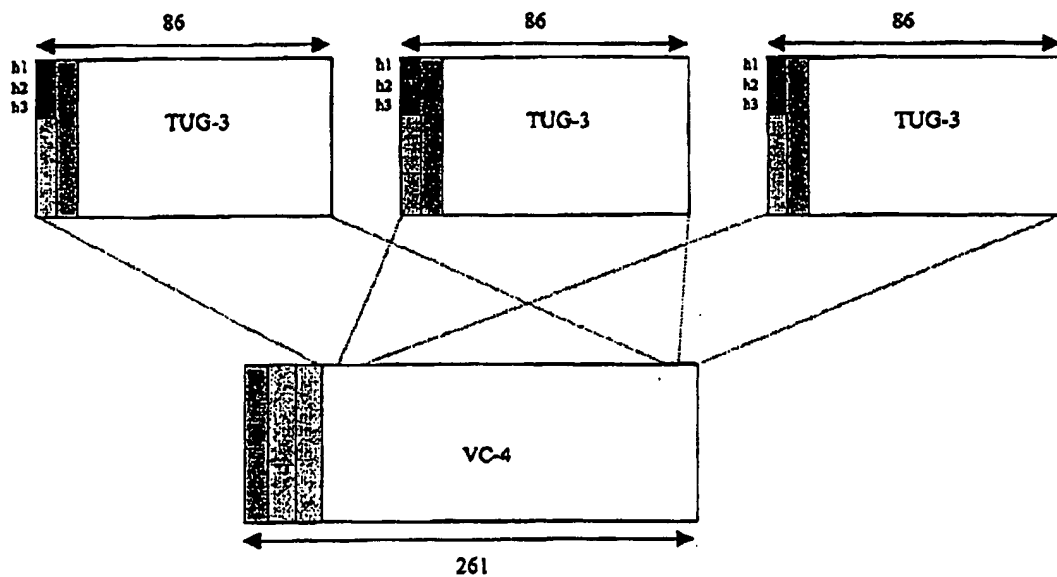
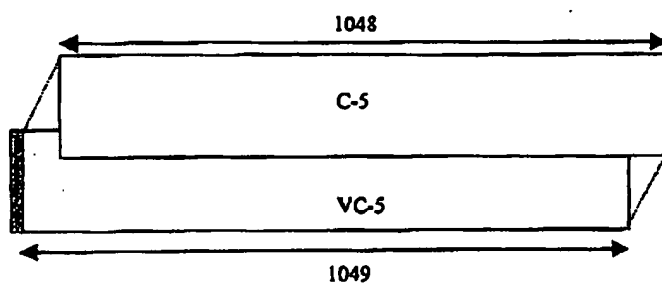**FIGURE 10**
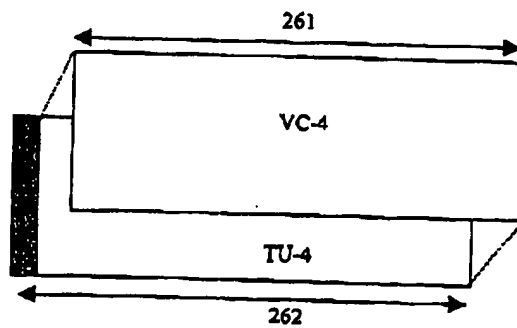
FIGURE 11
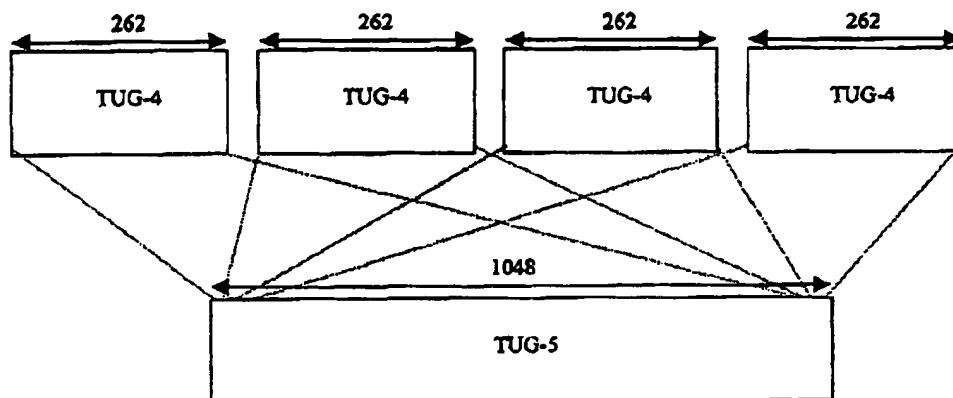
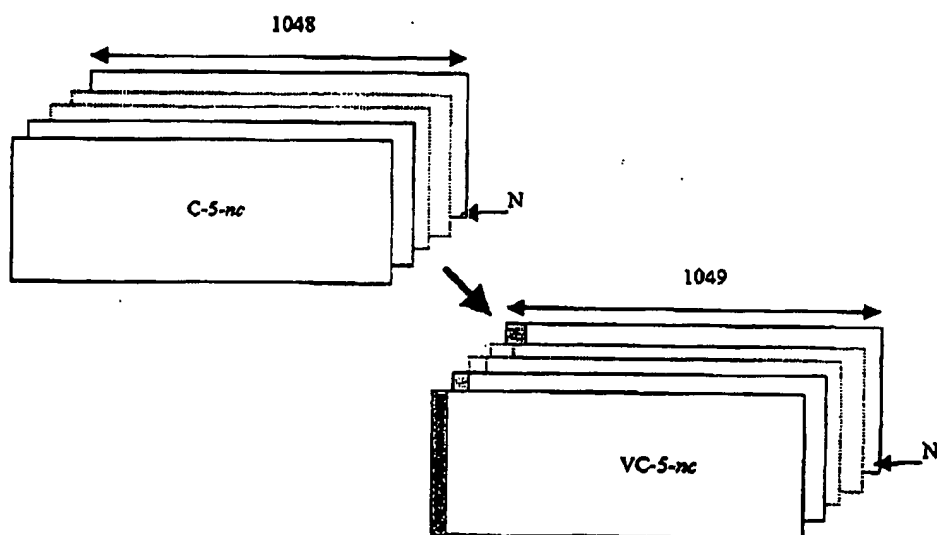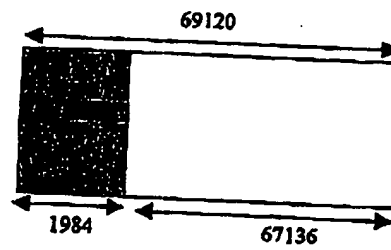**FIGURE 12**
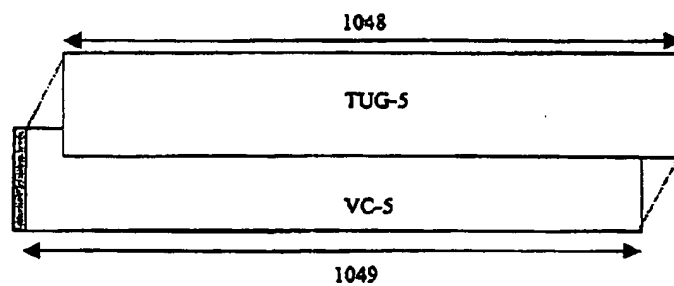
FIGURE 13
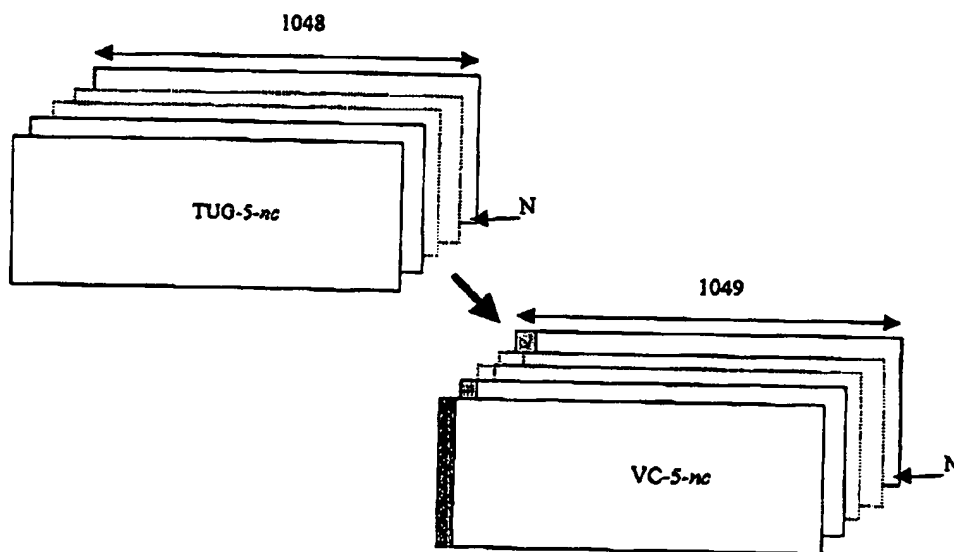
FIGURE 14
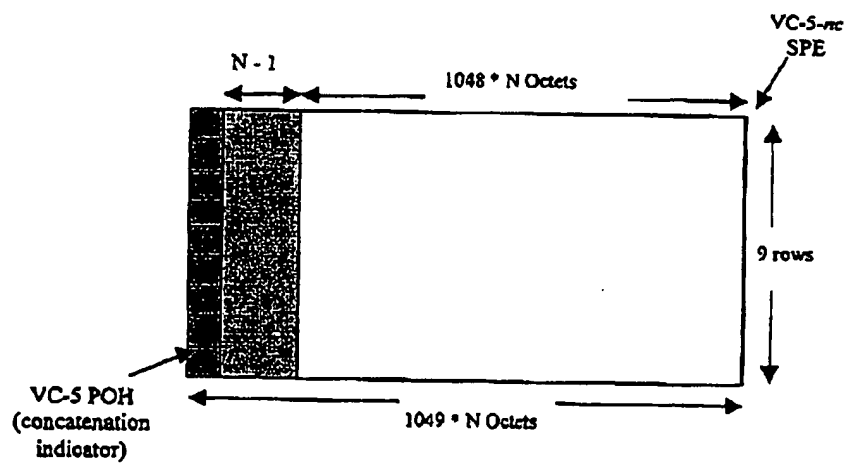
FIGURE 15

FIGURE 16

FIGURE 17

FIGURE 18

FIGURE 19

FIGURE 20

FIGURE 21